BIC Fiber Tests + Cosmics @Regina - Update 7

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Weekly Barrel Imaging Calorimeter (BIC) Meeting, October 10, 2023

Timeline - September/October

- **Past Plan**
  - July & August: Spectrophotometer, Photodiode, Npe tests
  - August 29: Presentation to bECAL Group; discussion of results
  - August 30-Sept 4: organization of evidence for Sept 13 Review
- Continuing work
  - Oct 02: **Npe station**: measure more double-clad fibers
  - Oct 09: **Photodiode station**: measure more double-clad fibers
  - Oct 30: **Spectrophotometer station**: recalibration
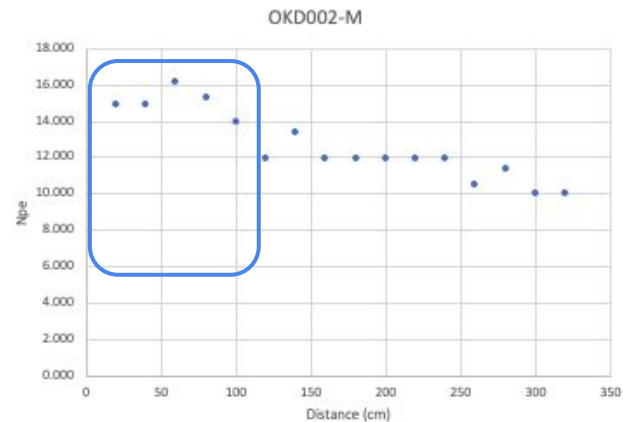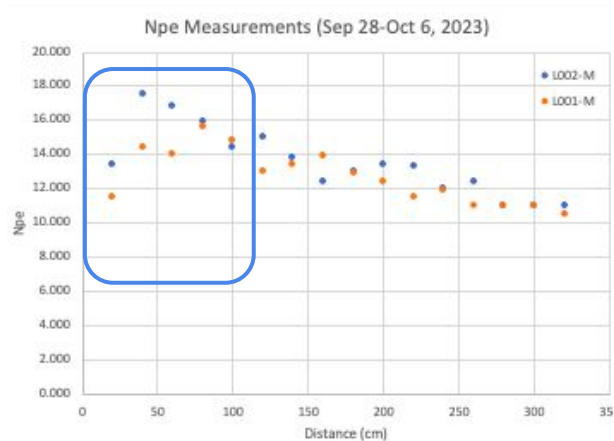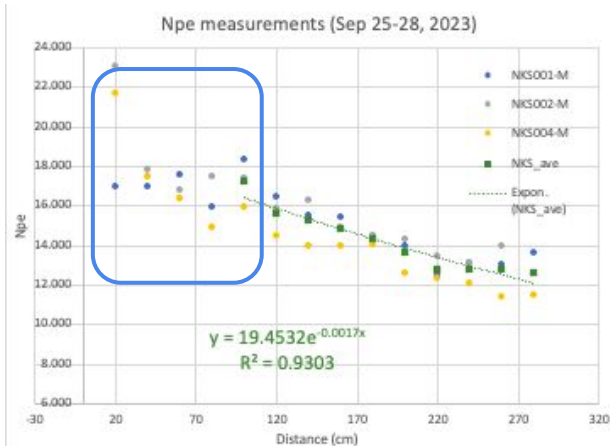 - Ongoing: **Baby BCAL beam and cosmics**; shipment in late Oct.

Npe Comparisons

- **More NKS, L and OKD** fibers measured.
- SiPM-PMT coincidences.
- Noise-subtracted comparison:
  - 14 distances for NKS,
  - 16 for L and OKD.
- Analysis scripts: multi-peak finding and light calibration
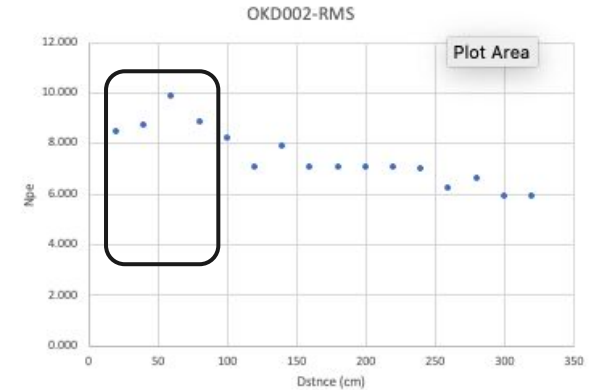- Previous: OKD > NKS > L.
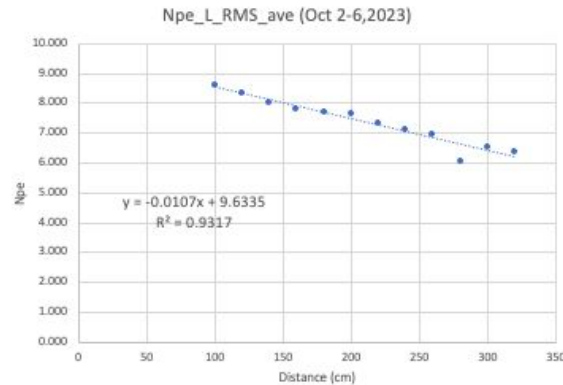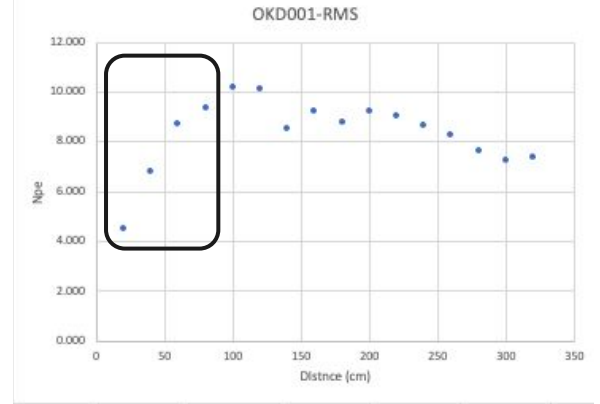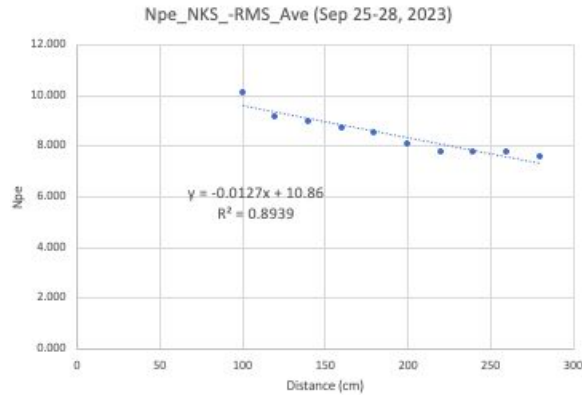
Npe - Data Quality

Poor measurements close to SiPM

Npe - RMS

No grease!

Npe_NKS_-RMS_Ave (Sep 25-28, 2023)

$y = -0.0127x + 10.86$
$R^2 = 0.8939$

OKD001-RMS

Npe_L_RMS_ave (Oct 2-6,2023)

$y = -0.0107x + 9.6335$
$R^2 = 0.9317$

OKD002-RMS

Plot Area

Npe - Kuraray-Single vs Luxium

No grease!

Attenuation Length (Npe Station)

$y = -0.0014x + 2.8167$
$R^2 = 0.9823$

$y = -0.0015x + 2.4101$
$R^2 = 0.9134$

- ln(L_ave-M)
- ln(NKS_ave-M)
- Linear (ln(L_ave-M))
- Linear (ln(NKS_ave-M))

Npe_RMS Trends

$y = -0.0127x + 10.86$
$R^2 = 0.8939$

$y = -0.0107x + 9.6335$
$R^2 = 0.9317$

- L_RMS_ave
- NKS_RMS_Ave
- Linear (L_RMS_ave)
- Linear (NKS_RMS_Ave)
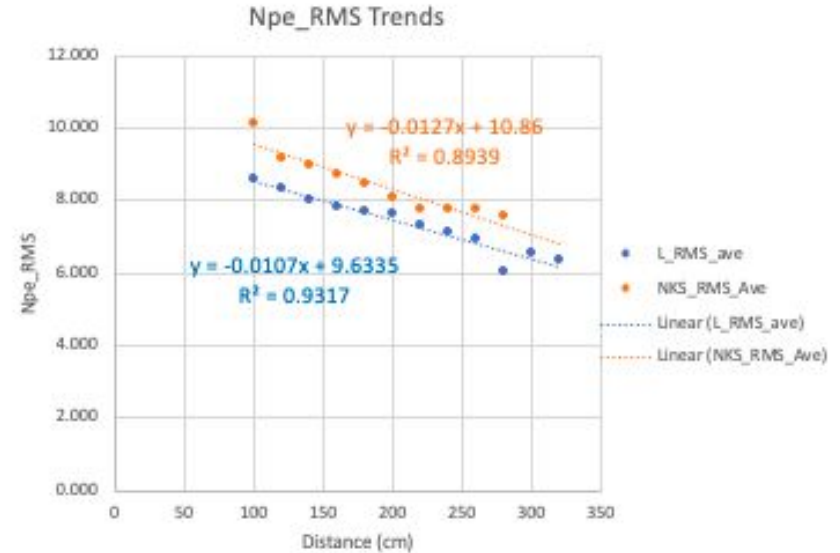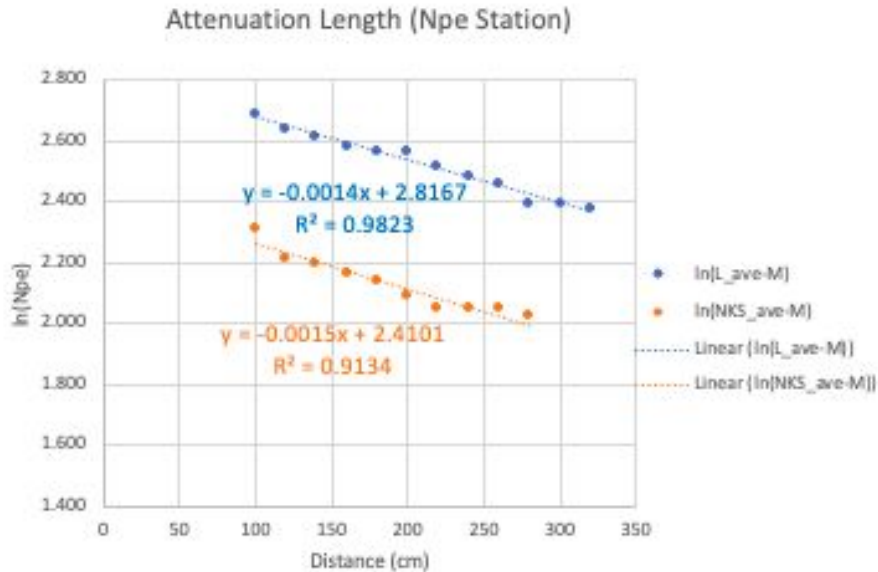
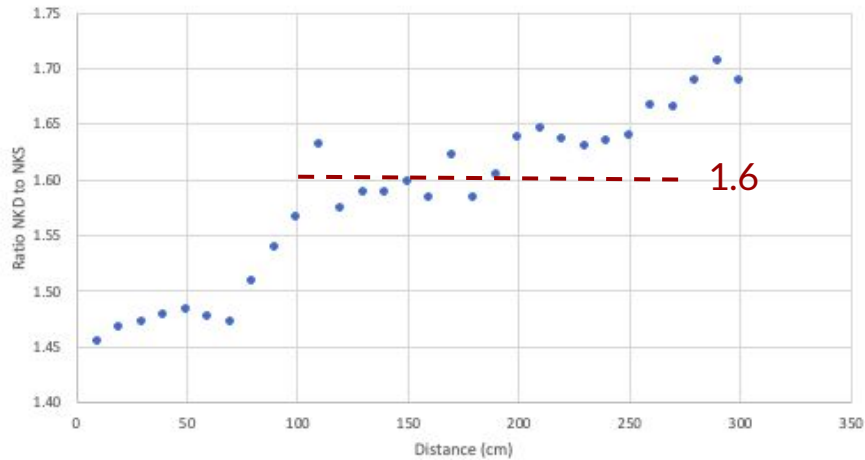**Single-exponential fits beyond 100 cm**

6

Npe Station - continue studies

- Measure additional fibers: ✓Luxium, ✓double-clad OKD; **next: NKD**.
- ✓Quantitatively compare to photodiode results for same fibers.
- ✓Reproducibility checks.
- Examine fiber polish in imager. Repolish if needed.
- Retake **noise spectrum** and recheck analysis to understand results.
- Longer running times and normalize more accurately.
- Advanced fitting.
- On Oct 11 move puckboard to photodiode/spectrophotometer station.
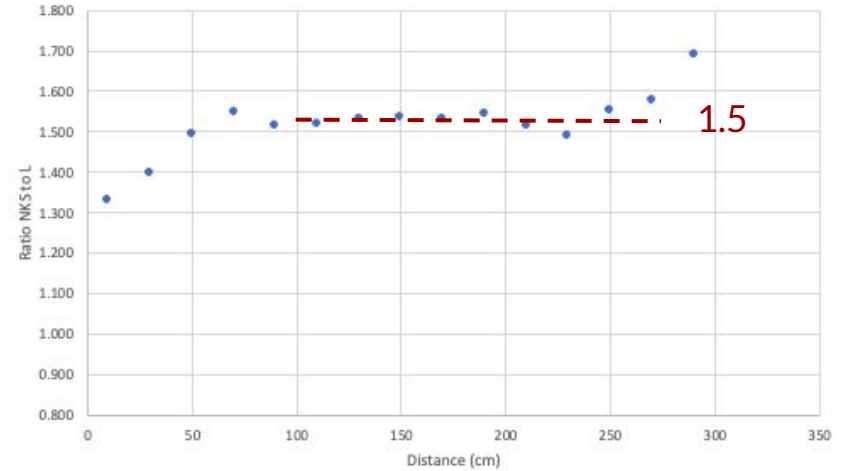
Photodiode Station - comparisons

Measurements With Optical Grease
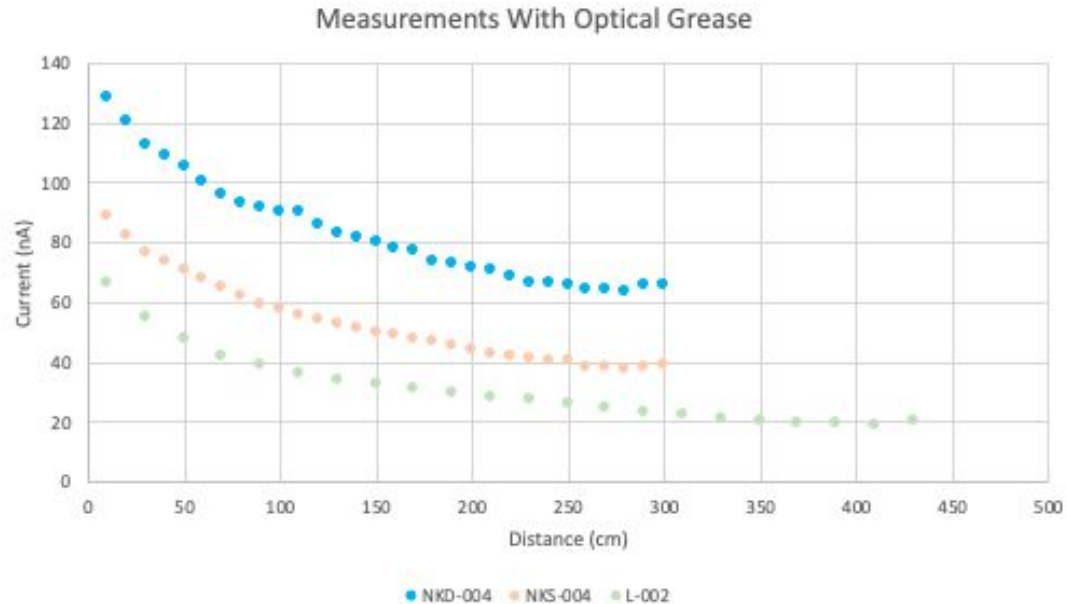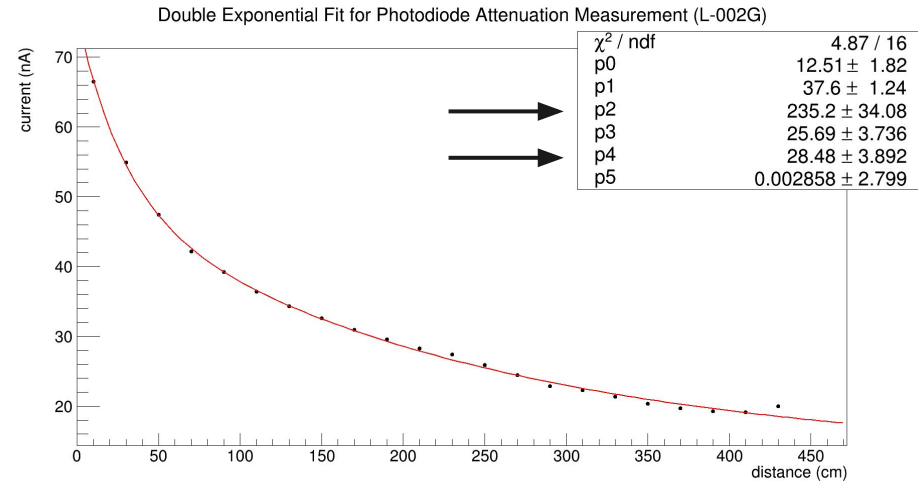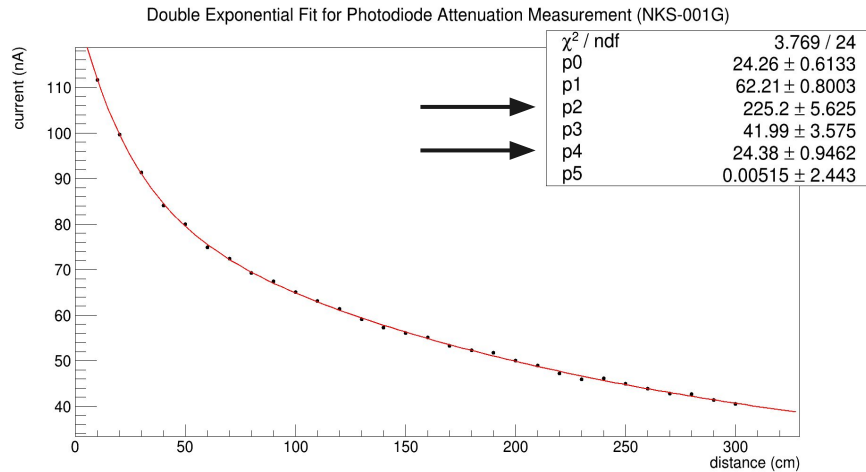
Photodiode Station - comparisons

NKD/NKS

NKS/L

Photodiode Station - double exponential fits

Double Exponential Fit for Photodiode Attenuation Measurement (NKS-001G)

χ^2 / ndf	3.769 / 24
p0	24.26 ± 0.6133
p1	62.21 ± 0.8003
p2	225.2 ± 5.625
p3	41.99 ± 3.575
p4	24.38 ± 0.9462
p5	0.00515 ± 2.443

Double Exponential Fit for Photodiode Attenuation Measurement (L-002G)

χ^2 / ndf	4.87 / 16
p0	12.51 ± 1.82
p1	37.6 ± 1.24
p2	235.2 ± 34.08
p3	25.69 ± 3.736
p4	28.48 ± 3.892
p5	0.002858 ± 2.799

Do not agree with GlueX; more work needed.

Photodiode Station - continue studies

- Fiber **elastic memory** from coils:
    - Upwards "bump" at 300.0 cm distance on Kuraray fiber measurements;
    - Luxium numbers have smaller errors; fiber curvature?
    - Kuraray: no "cure"; roll habit/ big bobbin; sample offered.
    - Luxium: possibly using heat but not recommended.
- Inconsistent measurements closer to photodiode.
    - LED pulses? Recheck cover over photodiode and screen around LED.
    - Continue with **short- and long-wavelength** components.
- Quantify/recheck: NKS, NKD, OKD, L - all with grease (more fibers).

# Sasha's Single- vs Double-Clad fibers

1. It may affect e/pi separation for eID and photon measurements (down to 100 MeV), and ToF measurements (e.g. to define z from the time difference between two sides) - and we need to develop our conclusion on all of these.

2. Our simulation has to have realistic light attenuation implemented (from Zisis's measurements; one exponent model is definitely not enough), and thresholds (equivalent 5-10 MeV per readout channel looks reasonable?).

3. As we discussed we don't expect any significant effect on resolution due to increased light yield (with double clad), because it is defined mainly by sampling fluctuations; however the fact that the energy is distributed among many channels (segmented in both transverse and longitudinal directions) with their own noise and threshold, may eventually affect the resolution, particularly for lower energy photons.

4. The light yield per channel along with thresholds may effect ToF measurements (and therefore z measurements), particularly at sector ends, when signal on the far side will be significantly attenuated.

5. Elke insists that on the negative rapidity end, we have to be capable to measure electrons as well as possible (important kinematical region with intermediate Q2), and having double clad fibers in imaging layers, where basically the whole shower will be confined in imaging layers in far end - it could be beneficial for us. Let's quantify it too.

6. If we decide to use double clad fibers for thin (imaging) layers, it is not necessary to use it for all five layers; moreover I see not so much meaningful to provide high light yield in the last imaging layers, as they locate at show max and provide highest light yield anyway. So if it is meaningful at all, only first couple of layers may give some effect.

SciFi Vendor Communications (week Oct 2)

- Kuraray:
  - Double-clad fibers use fluorinated polymers - longer procurement lead time (raw materials).
  - "Roll habit" (lift-up/elastic memory): no way to eliminate it. They are offering us sample shipment in larger-diameter bobbins (stock SCSF-78M, 1mmφ, single, Non-S type).
- Luxium:
  - LLP timetable?
  - They ask for our test result details. Their tests show attenuation length > 400 cm.
- Other:
  - Figure-of-merit calculation for single vs double? (shower, MIP, etc).
  - Figure-of-merit calculation for vendor? (dimensions, performance, price, delivery).
  - Single alone, or single-double order and LLP: timetable? notify vendors asap.

Cosmics run and analysis

adjustable

fixed

Longitudinal View
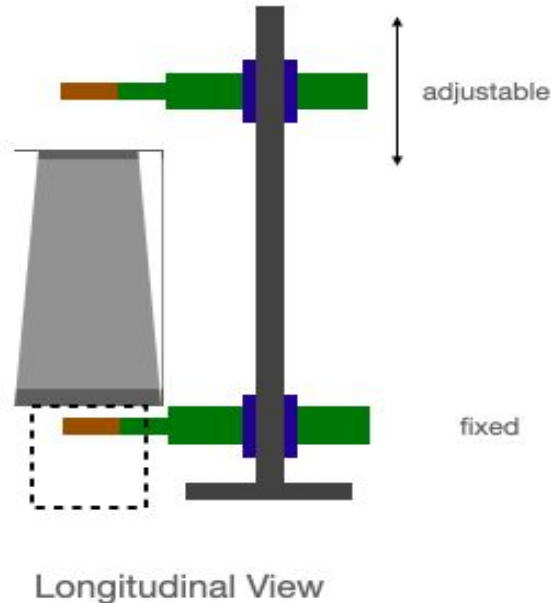
- <u>Tests in Hall D</u>:
  - Paddle trigger; 32 SiPM channels (N and S). S2 & S3 intermittent.
  - Data in Mode 10 (raw+pulse) and at 3 bias sets.
  - SiPMs running **hot**. Installed Chiller.
- <u>Hardware set up</u>: discriminators firing as expected.
  - Waveforms look very nice; clear tracks through vertical "stacks" of cells .
- <u>Analysis</u>:
  - Checks make sense (vertical cuts, North vs South).
  - Statistics low! Count rate 0.008-0.012 Hz.

Cosmics Run - new setup

Example Cosmic Readout

Side 1
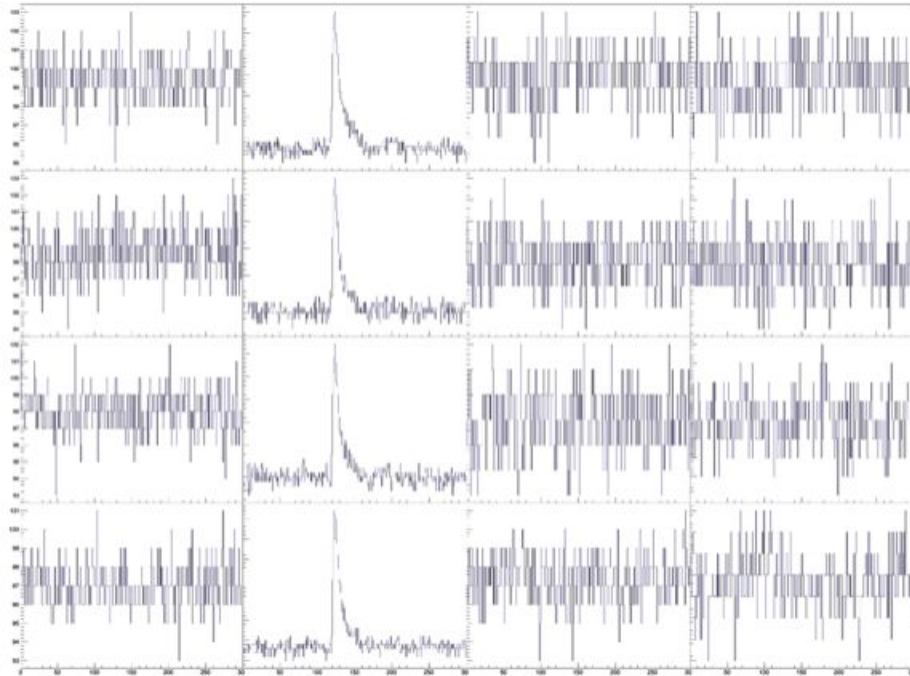
Side 2
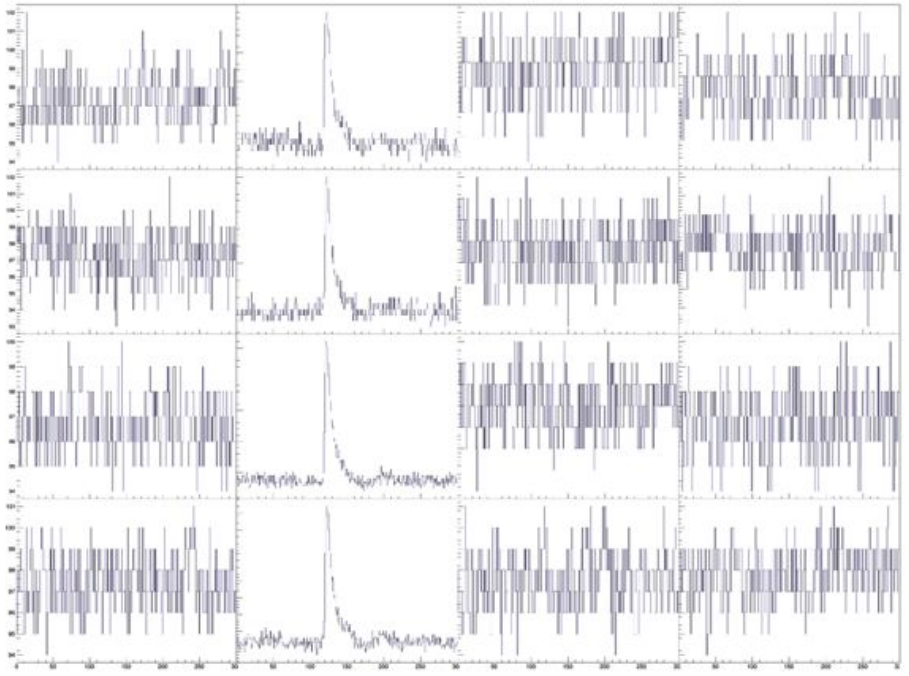
Cosmics energy deposition
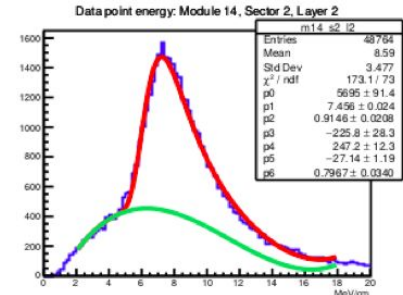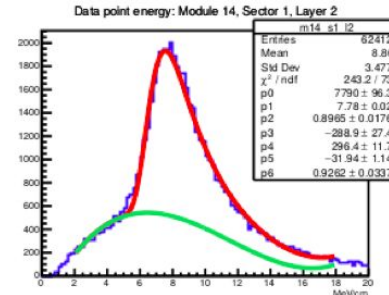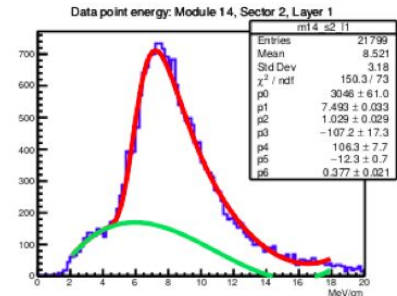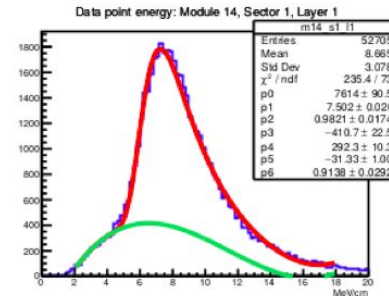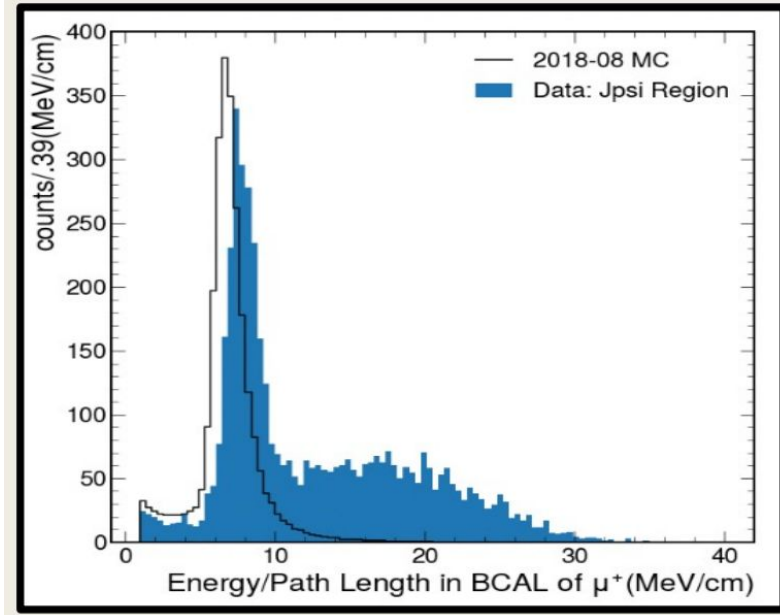
Using March Data-Driven Constants

- VERY PRELIMINARY!
- Examine channels with best determined gain constants from March
  (most central along e+ beam)

- Cut to require vertical muons only
- March gains convert from ADC units to rough energy
- Divide by each channel's length
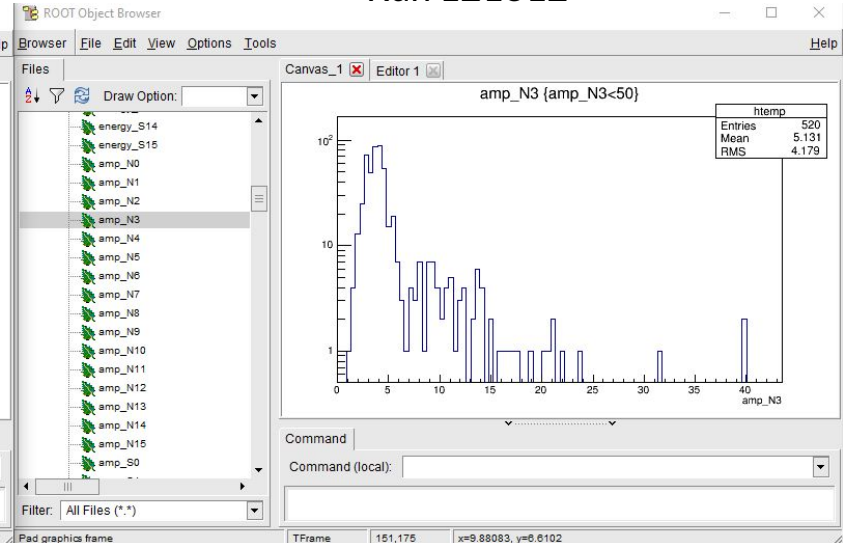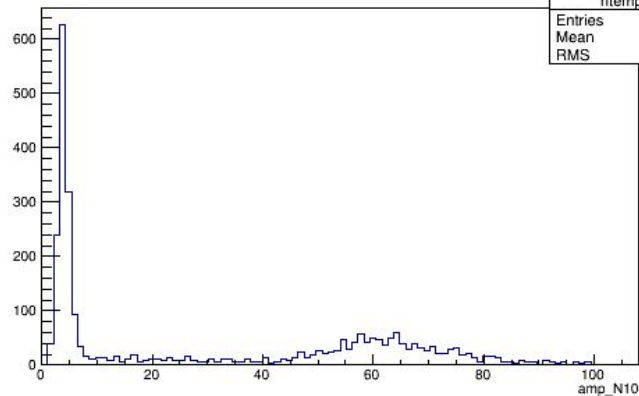- Results in right ballpark at least

Cosmics energy deposition - Layer

Baby BCAL
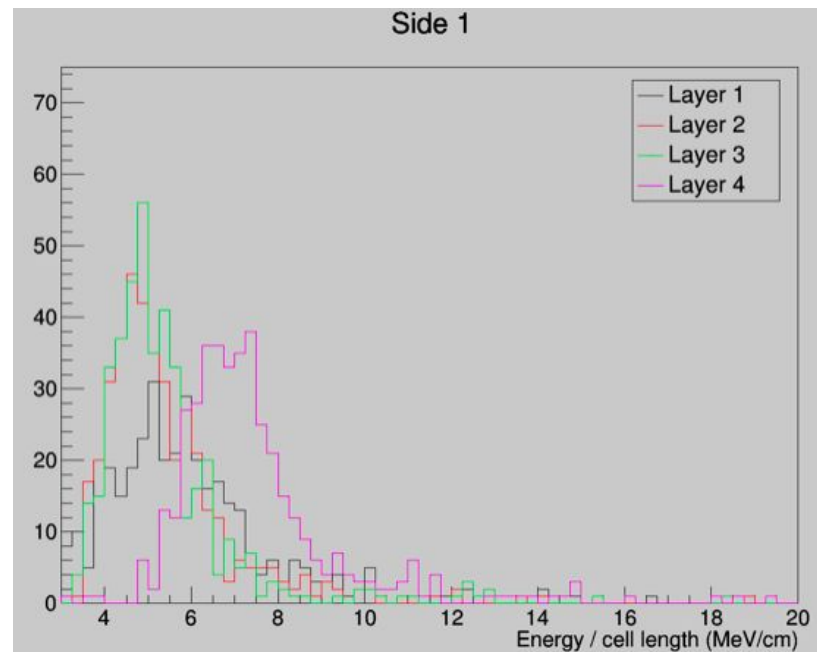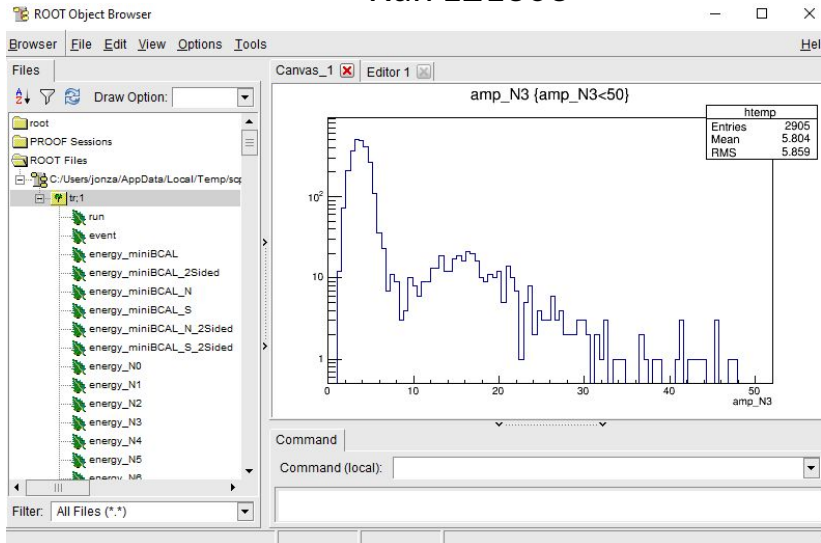
Run 121303

Run 121312

Cosmics energy deposition - Layer 3

Run 121303

Run 121312
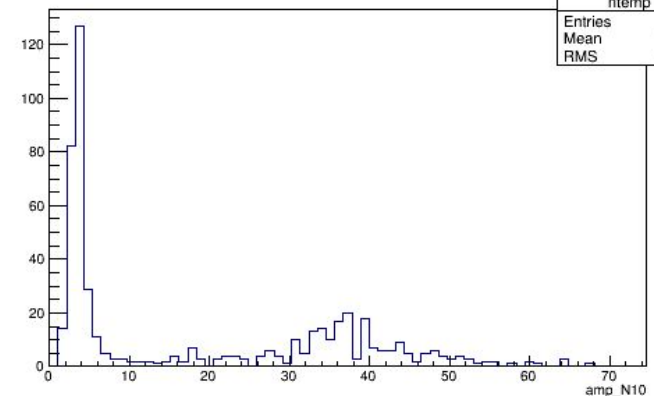
Summary

- **Review and Fiber Decision: Nov 14-16**
- **Fibers:** S. Oreśič, M. Kerr, ZP; Cosmics: M. Kerr, J. Zarling, ZP
  - Npe measurements wrapping up; no absolute numbers possible.
  - Photodiode, week Oct 9; recheck absolute numbers. Blacken ends.
  - Spectrophotometer, week Oct 30 (ZP in Regina).
- **Baby BCAL**:
  - Beam tests Eres & Npe: M. Kerr, J. Zarling (resumed week of Oct 2)
  - Cosmics gain calibrations: J. Zarling, ZP (weeks Oct 2, Oct 9, Oct 16)
  - Baby BCAL to ANL: week Oct 23
- **GlueX BCAL Npe**: M. Kerr, J. Zarling (start after fibers are done)

Backup Slides

Npe Station - Setup PMT

- puck board and runner
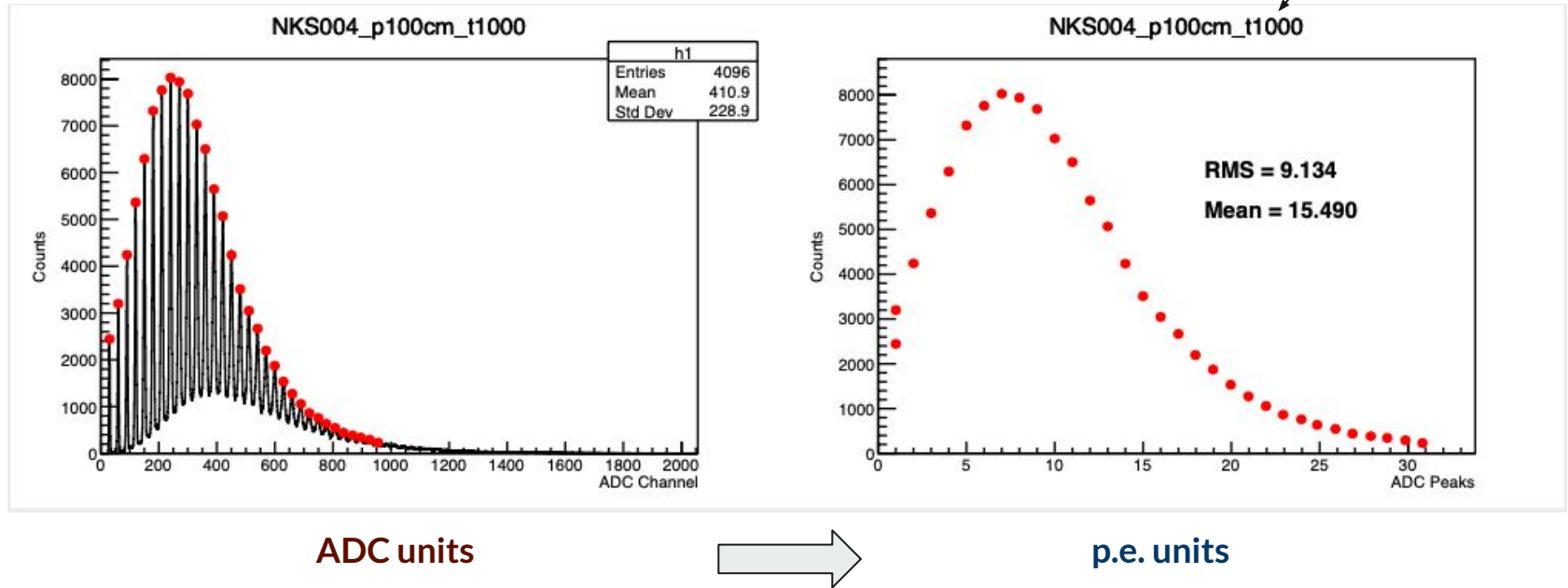- Stronger ^{90}Sr
- Ambient light control
- Coincidence with PMT

Optical grease

^{90}Sr

Npe Station - Setup SiPM

- Hamamatsu Module: high resolution, low noise, temp control
- Alignment
- Reproducible coupling

No optical grease
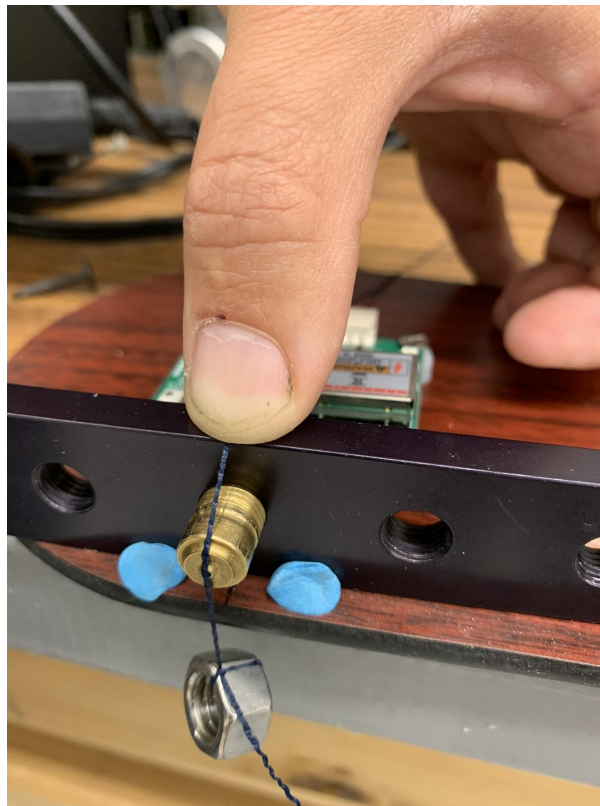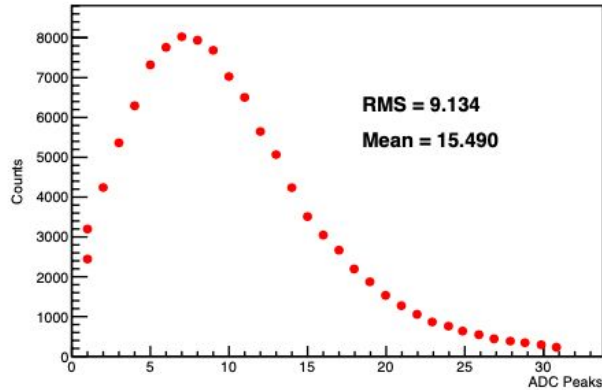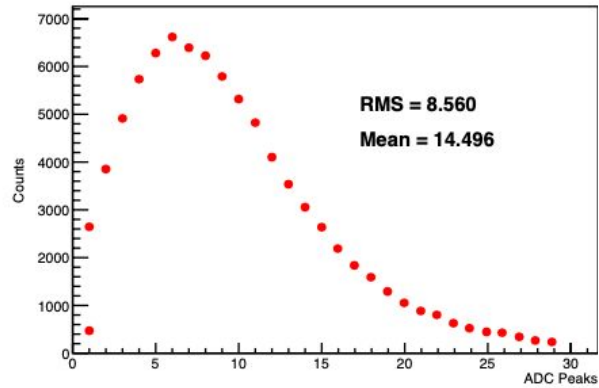
Npe - Peak finding & calibration

10 min running

NKS004_p100cm_t1000

h1	
Entries	4096
Mean	410.9
Std Dev	228.9

NKS004_p100cm_t1000

RMS = 9.134

Mean = 15.490

ADC units ⟹ **p.e. units**

Npe - Comparisons - 90Sr at 100 cm
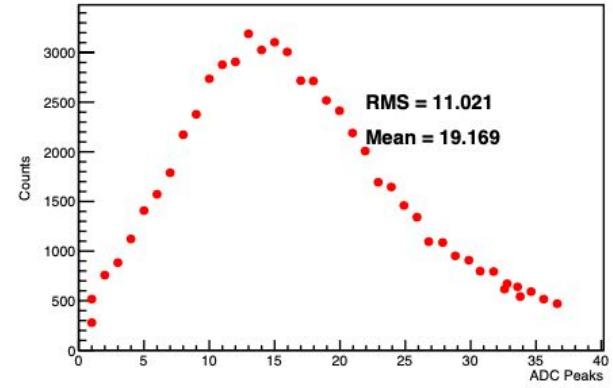
5 min running

No grease!   NKS/L = 6.4%, NKD/NKS = 20%

Npe - Comparisons - 90Sr at 140 cm

NKS004_p140cm_t1000

RMS = 8.843
Mean = 14.992

L001_p140_t1150

RMS = 8.270
Mean = 13.999

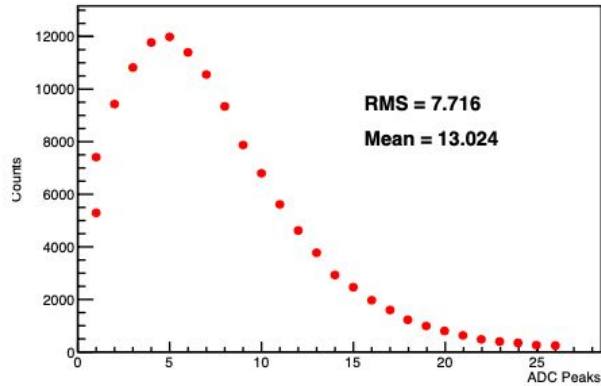OF001_p140_t500

RMS = 12.124
Mean = 21.069
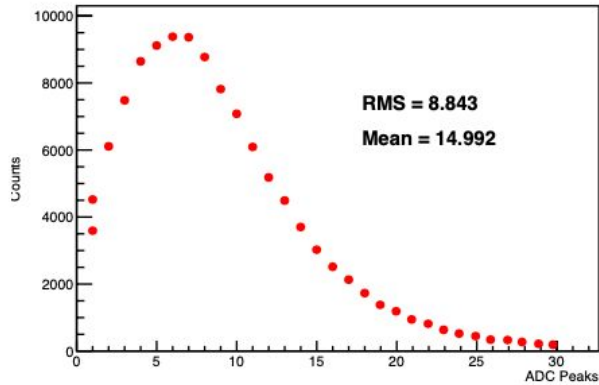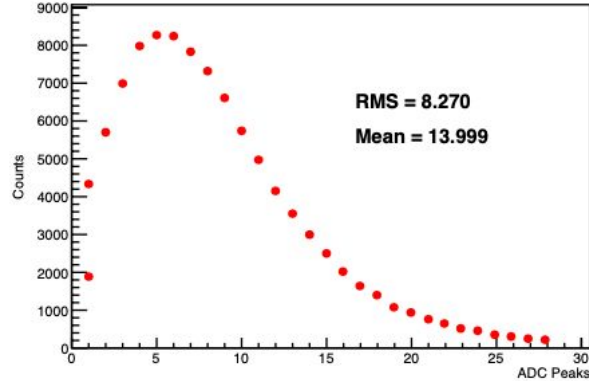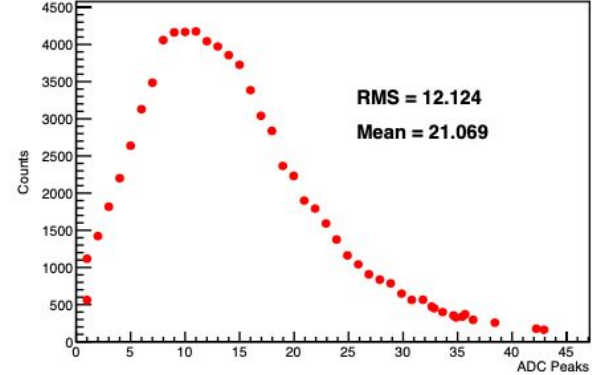
No grease!   NKS/L = 6.7%, NKD/NKS = 29%
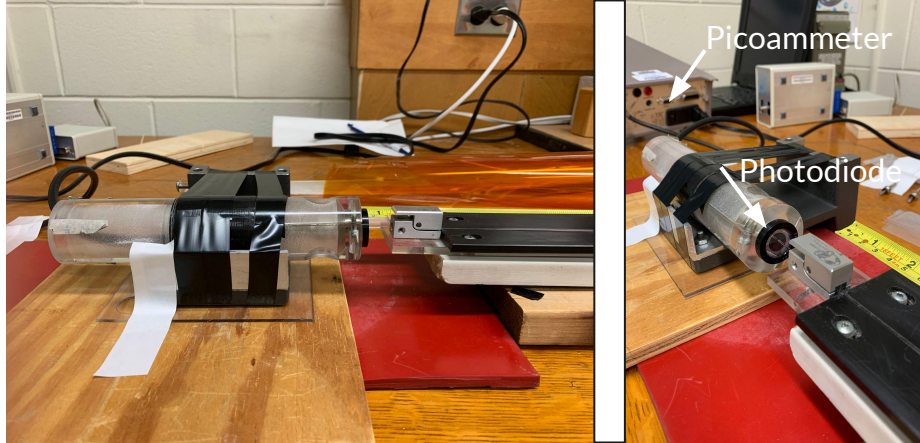
Npe - Comparisons - 90Sr at 200 cm
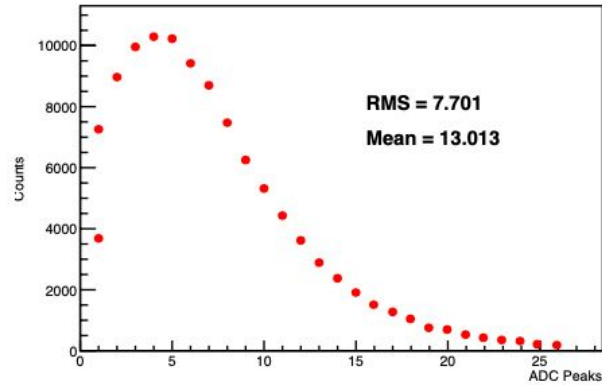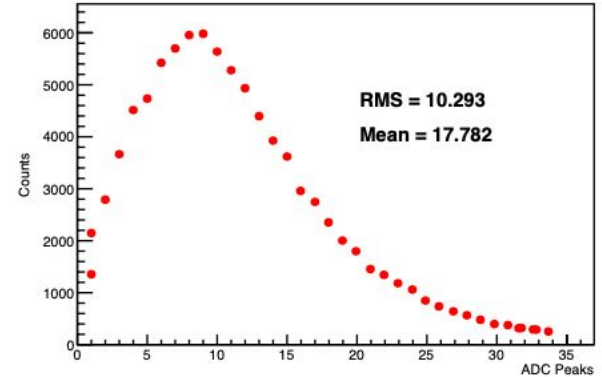
No grease!   NKS/L = 0.3%, NKD/NKS = 27%

Photodiode Setup


- Fiber laid in groove of polyurethane tray, polished end on photodiode.
- LED powered by power crate at 3.8 V, which corresponds to ~0.041 A.
- Picoammeter readings taken at 10.0 cm intervals, 10.0 cm to 300.0 cm.
- **Several NKS, L and NKD fibers tested.**

I - intensity
I_0 - initial intensity
x - distance along fiber
λ - attenuation length

Attenuation Length Calculation

$$I = I_0 \cdot e^{\frac{-x}{\lambda}}$$

- **NEW**: Adjusted attenuation length calculation method to correspond with Kuraray's documentation:
- Attenuation length of single and double clad fibers should be > 400.0 cm when fit using a single exponential function between 100.0 and 300.0 cm

30
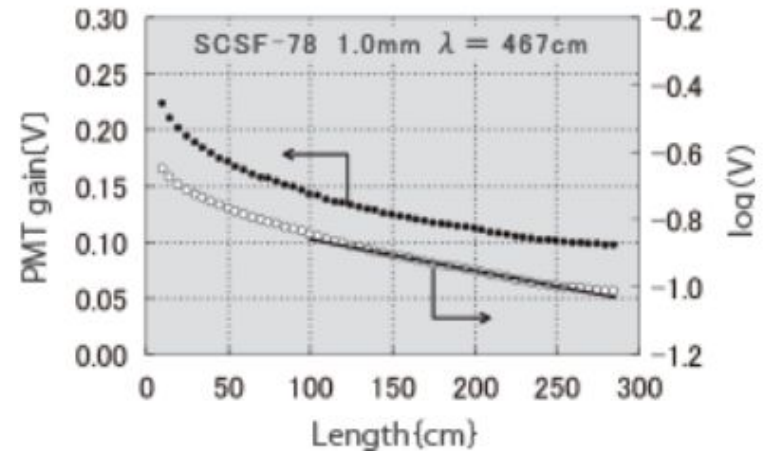
Attenuation Length Comparison (100-300cm)

| NKS-00i	λ (cm)	L-00i	λ (cm)	NKD-00i	λ (cm)
001	431±17	001	412±17	001	620±41
002	480±22	002	386±13	002	528±24
003	486±16	003	377±8	003	505±21
004	441±46	004	406±8	004	544±17
005	460±13	005	439±8		
001G	432±27	001G	425±8	001G	641±67
002G	532±42	002G	407±9	002G	529±41
004G	449±17	004G	567±66	004G	531±29

Spectrophotometer Set-up

- Fiber laid in groove of polyurethane tray (puckboard).
- Fed into **ADC0** of Ocean Optics SD2000[1] spectrophotometer; clip for stability.
- SD2000 connected to ADC (Ocean Optics ADC1000-USB Serial[1]), then connected to DAQ laptop via USB.
- Measurements in darkness; double layer of UV-absorbing film covering fibers.
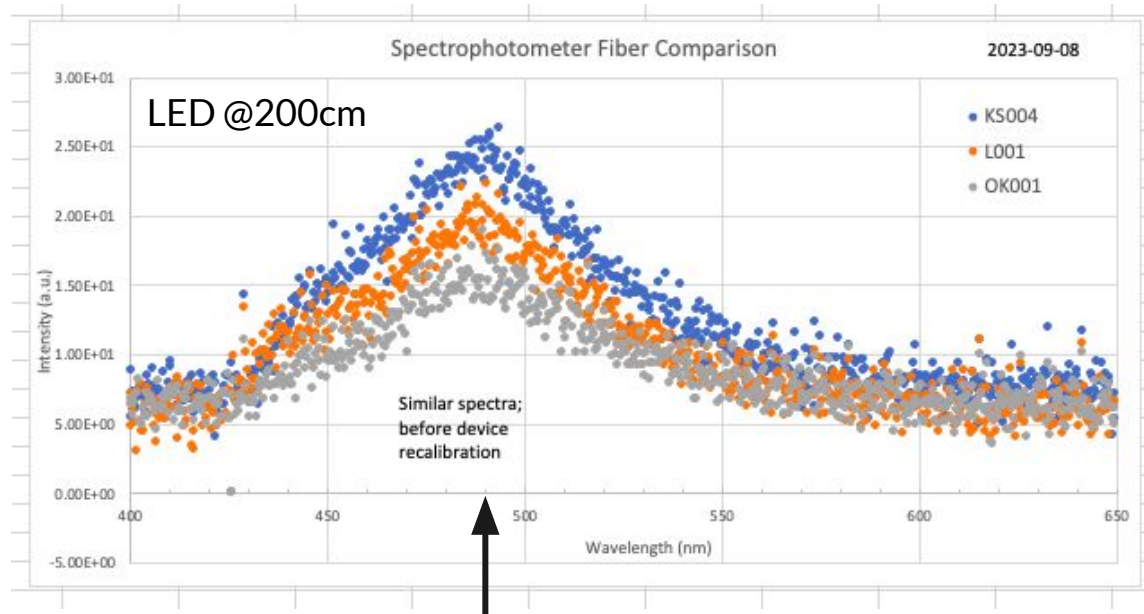
ADC0 port
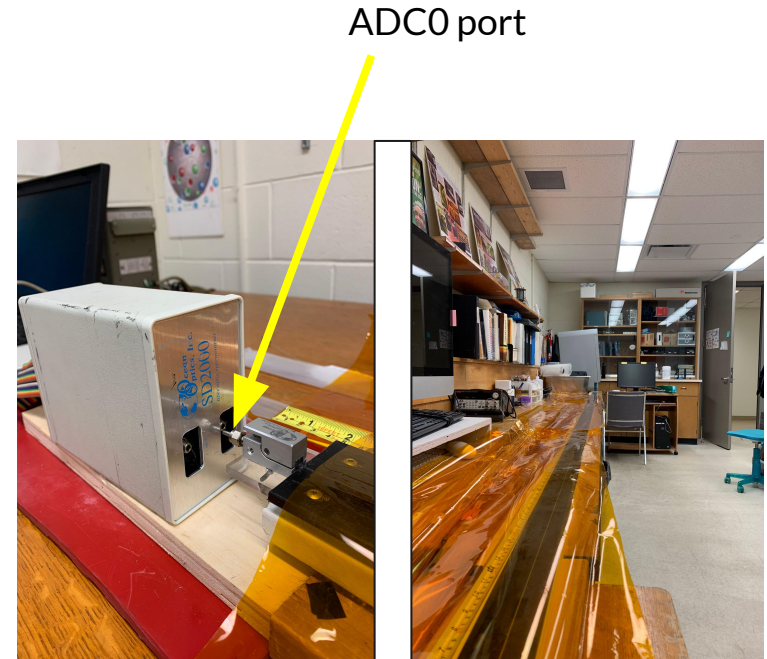
Spectrophotometer with fiber inserted (left); view down the tray holding the fibers (right)

[1]Ocean Insights, Orlando, FL, USA (www.oceaninsight.com)

# Fiber wavelength spectrum
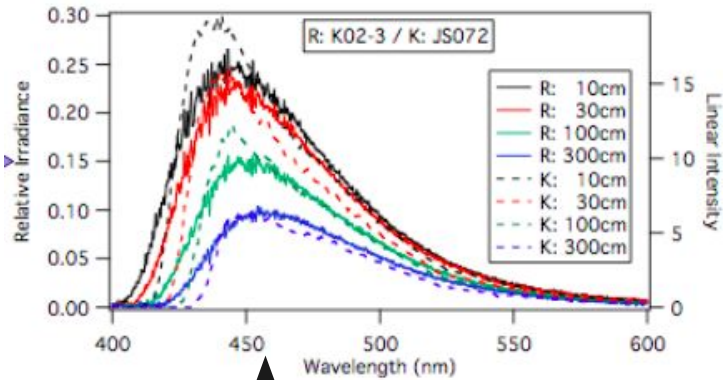
LED @200cm

LED @200cm

Spectrophotometer Station - continue studies

- Remeasure select NKS, NKD and L fibers in **ADC0**.
- Repeat with same fibers in **ADC1**.
- Re-calibrate CCD, using the D2J1470.SPEC calibration file.
- Remeasure same fibers in ADC0 and ADC1 and compare.
- Check calibration with new LEDs: 365, 390, 400, 450, 460, 470, 520 nm.
- Use Ocean Optics clear fibers for fiber-to-fiber connection with optical grease.
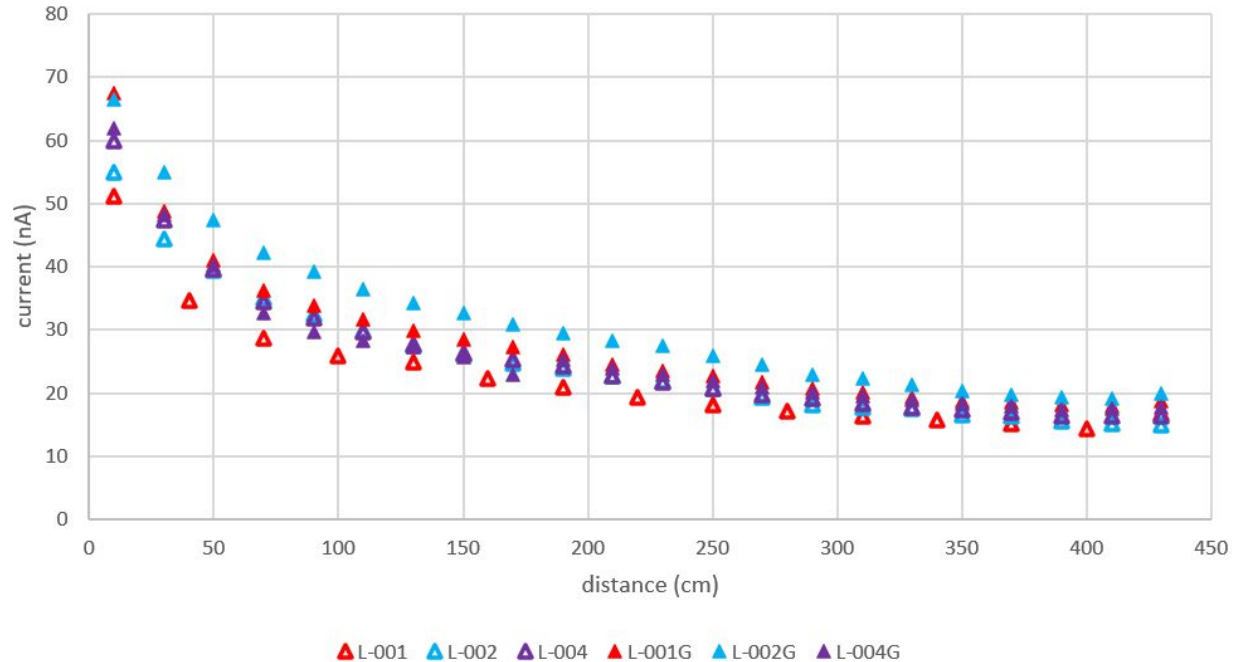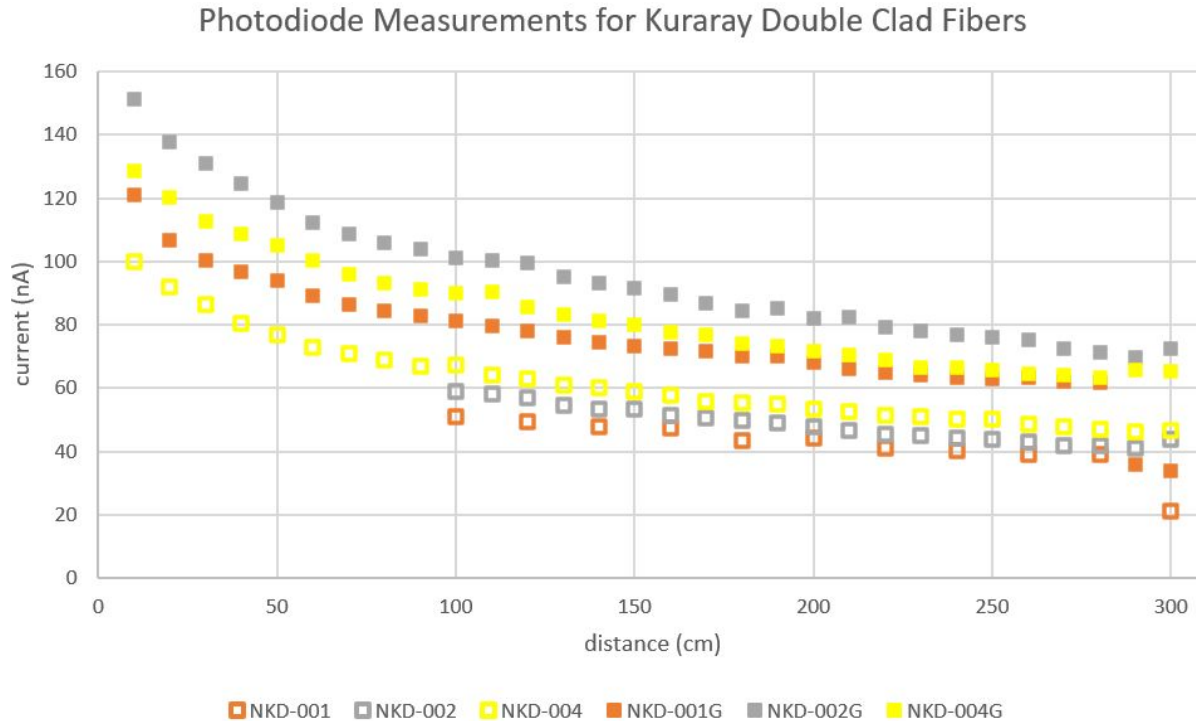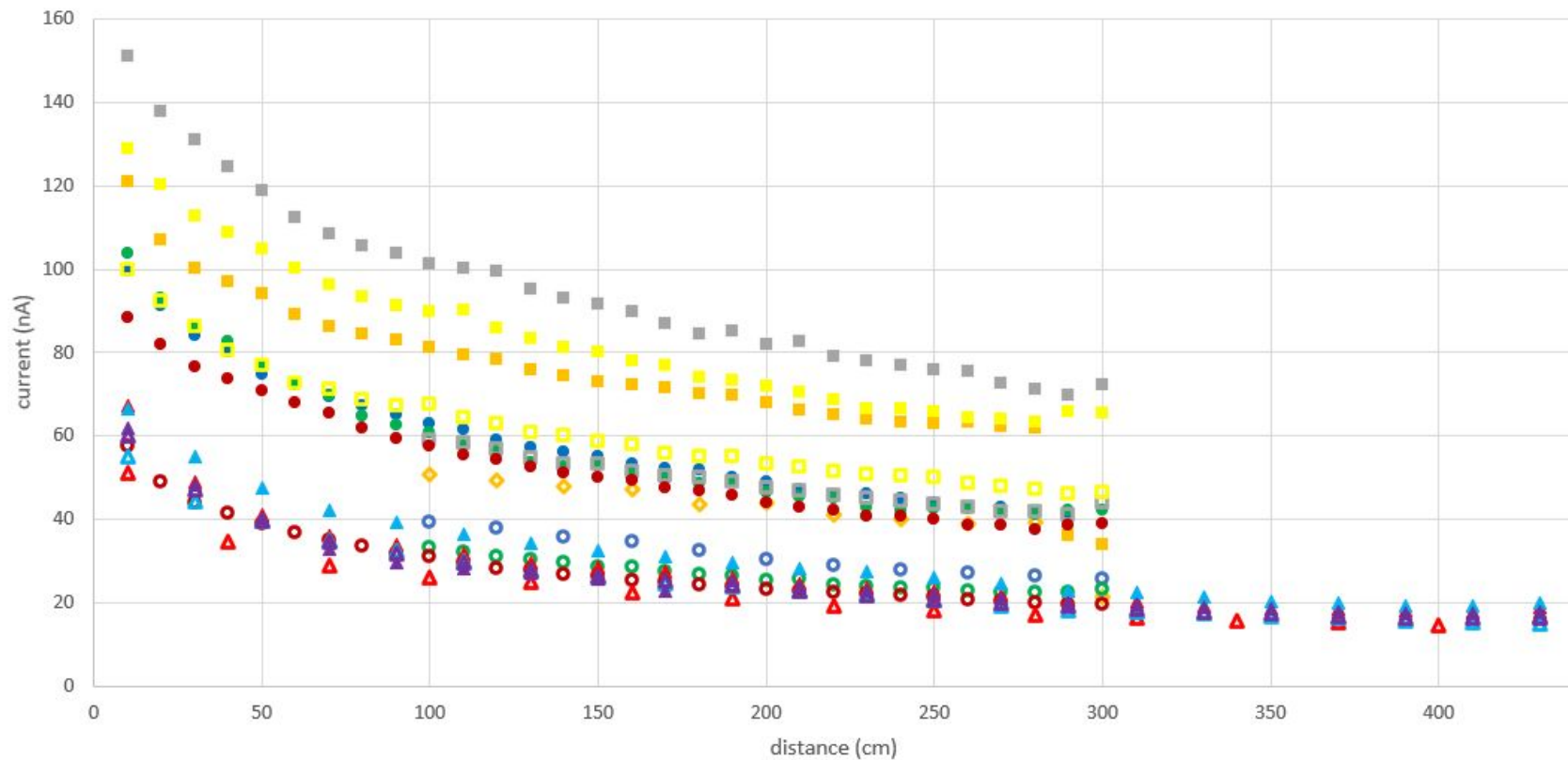
Kuraray Single Clad Results

Photodiode Measurements for Single Clad Kuraray Fibers
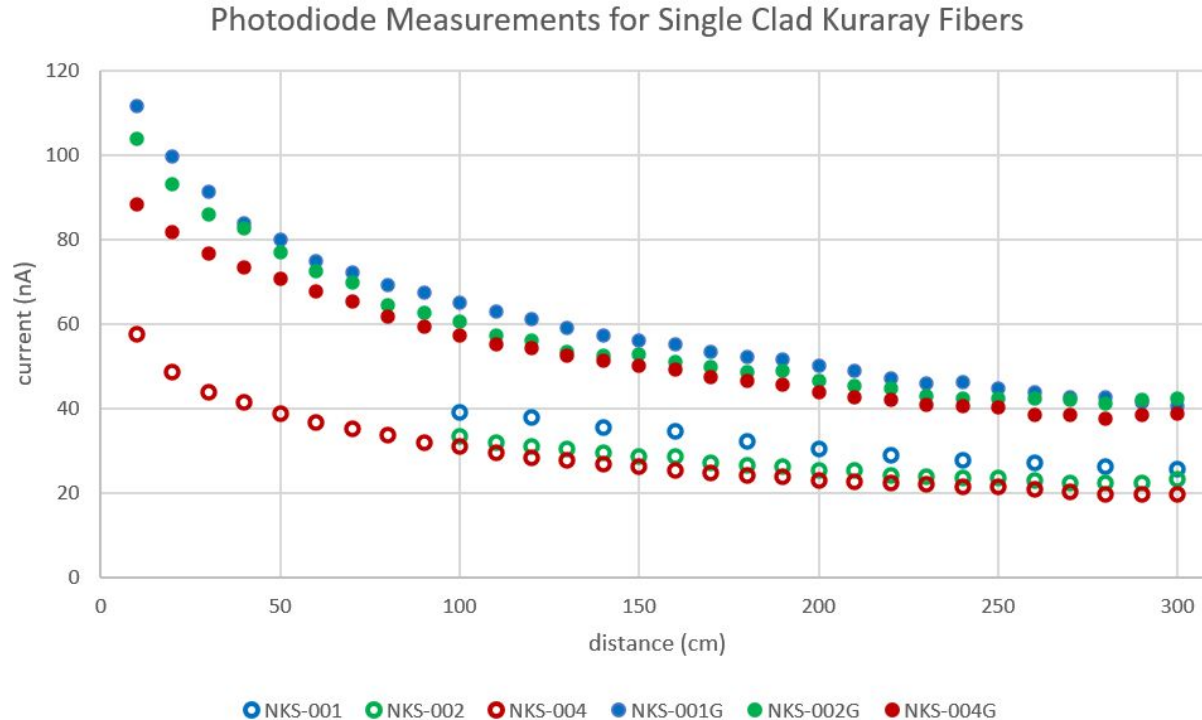
Luxium (Single Clad) Results

Photodiode Measurements for Luxium Fibers

Kuraray Double Clad Results

Photodiode Measurements for Kuraray Double Clad Fibers

Legend: NKD-001, NKD-002, NKD-004, NKD-001G, NKD-002G, NKD-004G

Absolute Readings for Non-Greased and Greased Fibers

No Optical Grease

Measurements With No Optical Grease

With Optical Grease
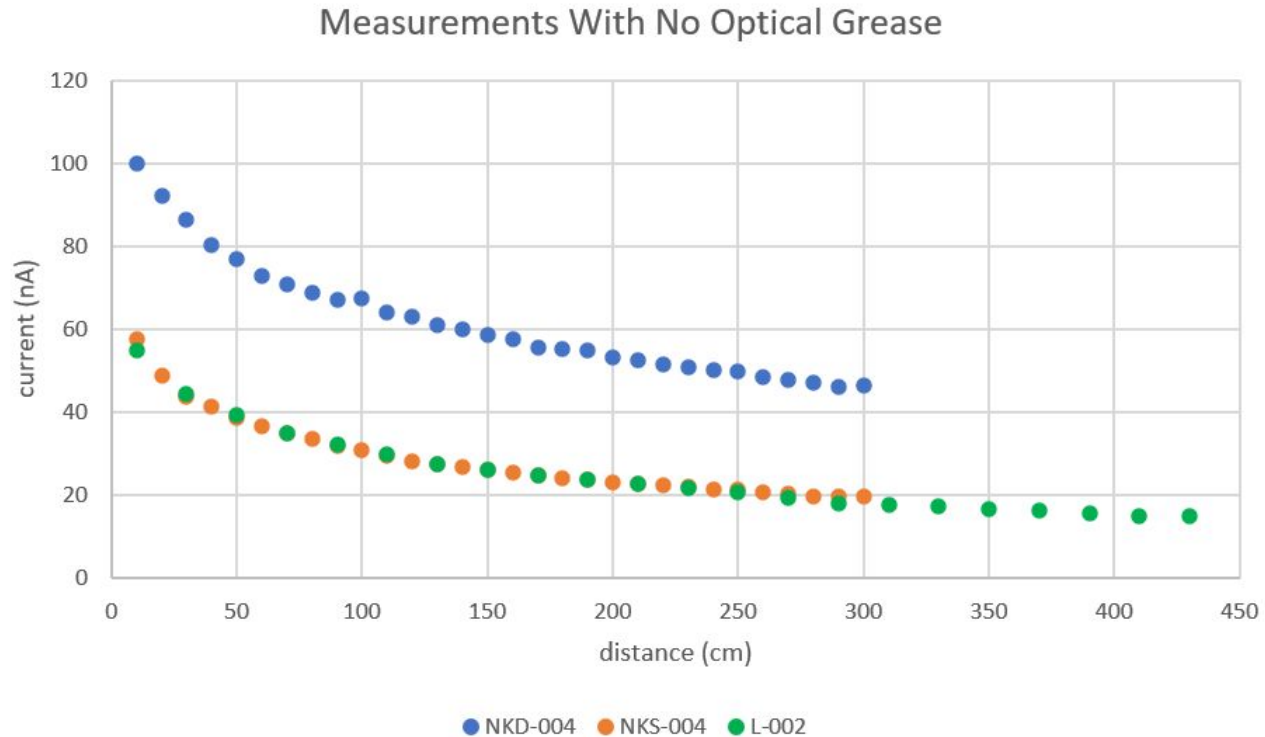
Measurements With Optical Grease
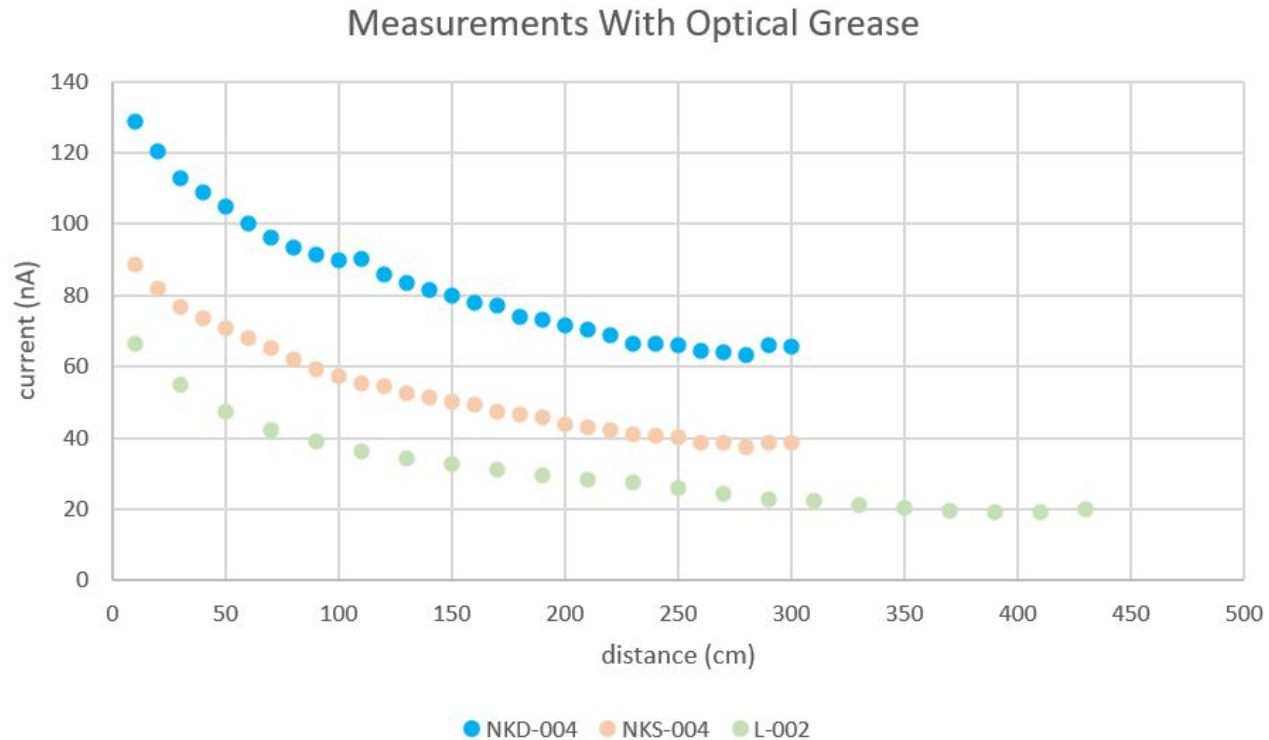
NKS-005

No measurement with optical grease taken

Kuraray Exponential Fit for Photodiode Attenuation Measurement (NKS-005)

χ^2 / ndf	2.465 / 19
p0	33.16 ± 0.3916
p1	459.9 ± 12.86

August 7 - August 11

Unpolished

First Polish
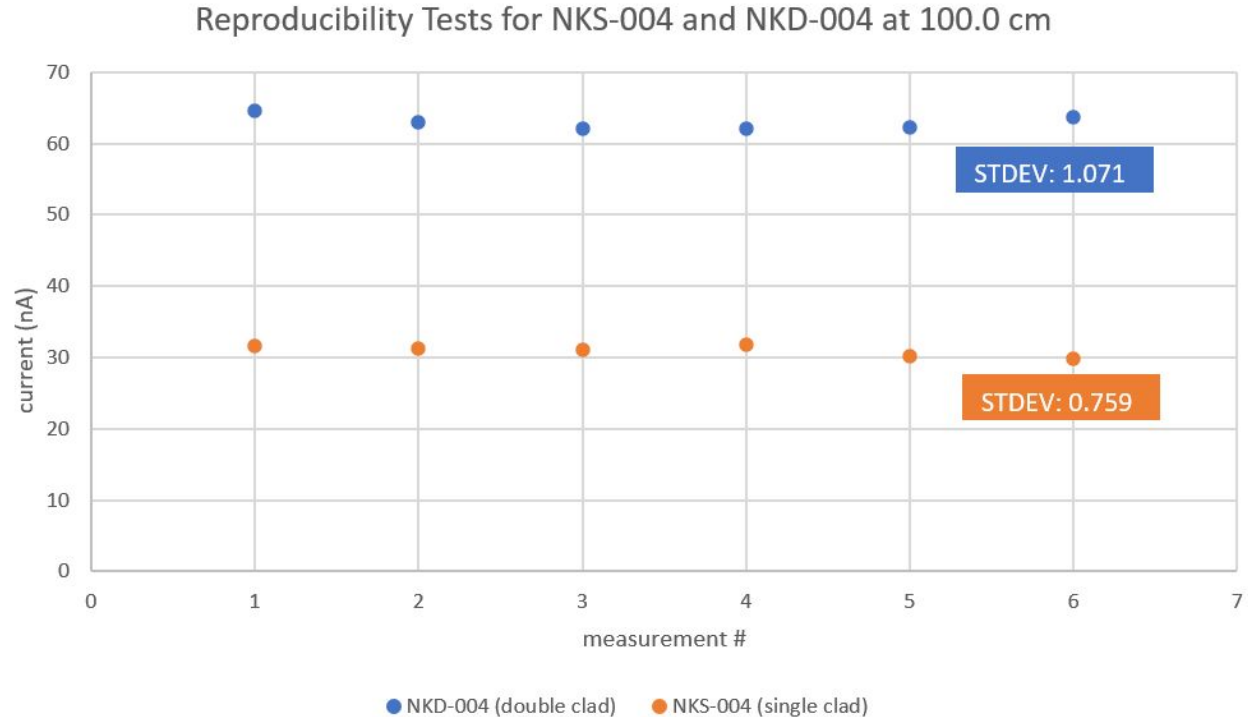
Second Polish
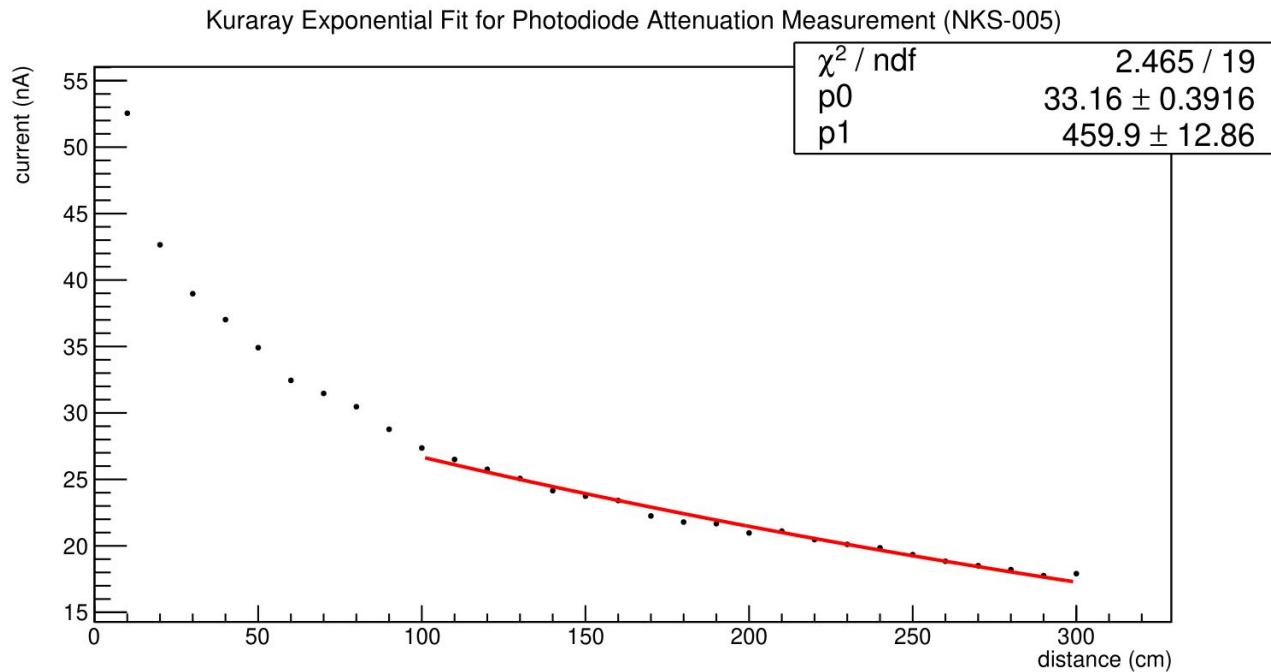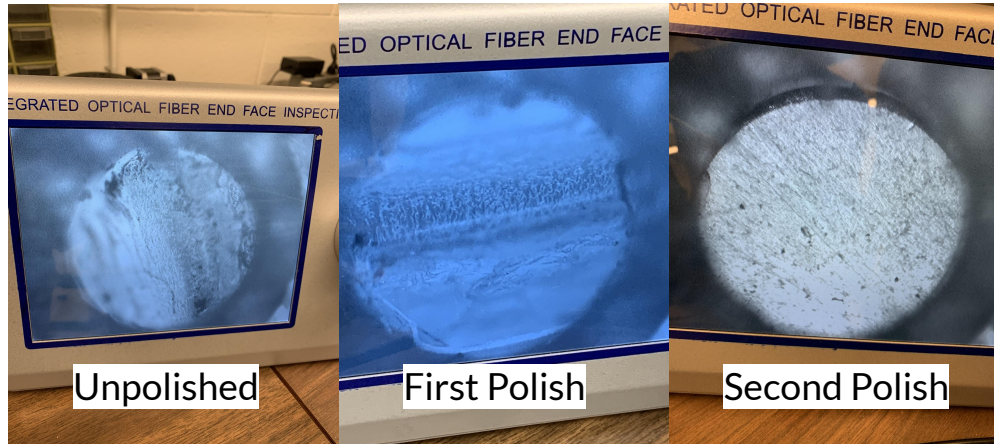
- **Luxium fibers** arrived!
  - Received **10 fibers**
  - **Unpolished**
  - **435 cm** long
- Luxium fibers were polished (x2) using previous **Fiber Polishing Station** and measurements were carried out using **Photodiode/Picoammeter Setup**
  - Measurements every 20.0 cm from 10.0 cm to 430.0 cm
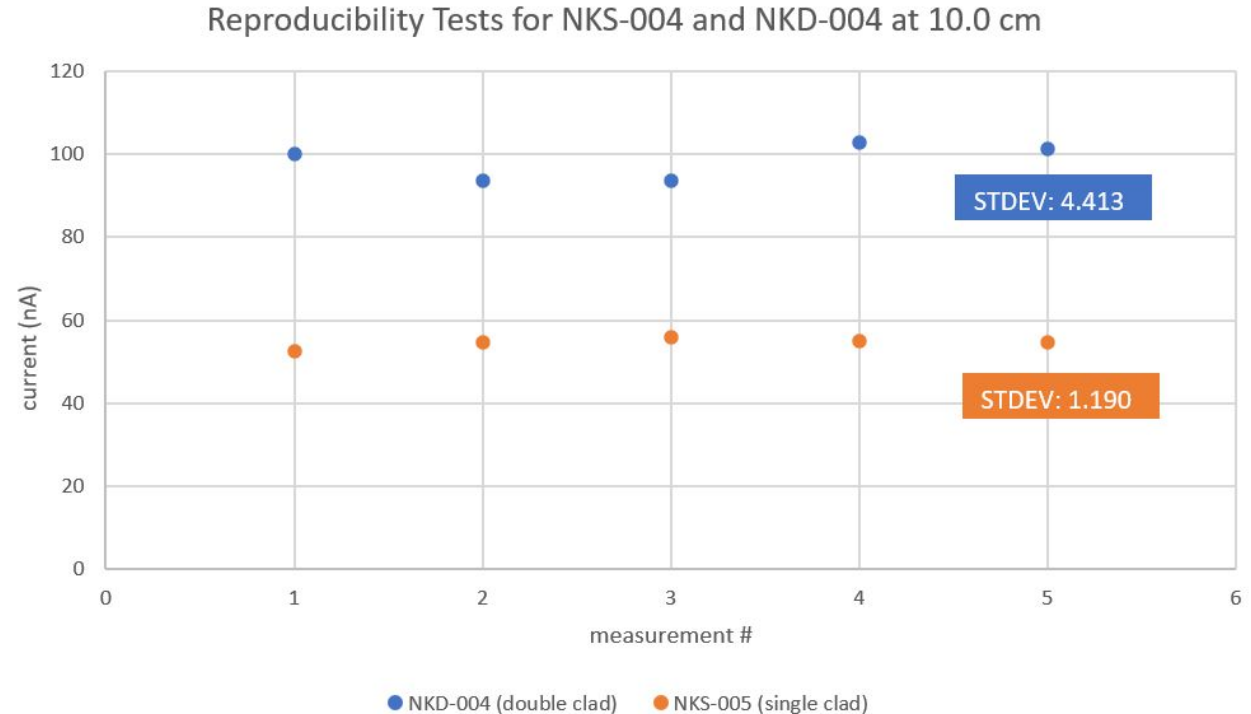- **Five Luxium fibers have been measured**

Reproducibility Tests - 100.0 cm

- 6 measurements @ 100.0 cm on NKS-004 and NKD-004
- Photodiode moved away from fiber and repositioned

Reproducibility Tests for NKS-004 and NKD-004 at 100.0 cm

STDEV: 1.071

STDEV: 0.759

current (nA)

measurement #

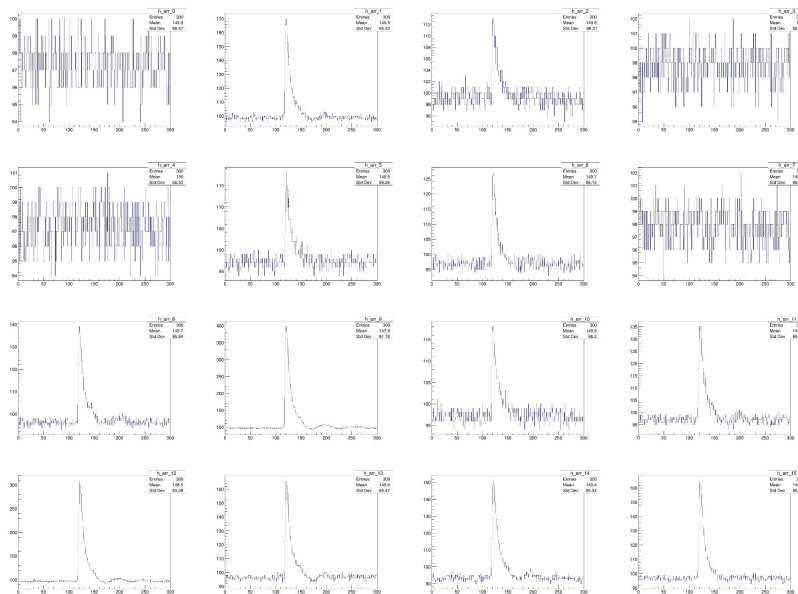● NKD-004 (double clad)   ● NKS-004 (single clad)

Reproducibility Tests - 10.0 cm

- 5 measurements @ 10.0 cm on NKS-005 and NKD-004
- Fiber moved away from photodiode and repositioned
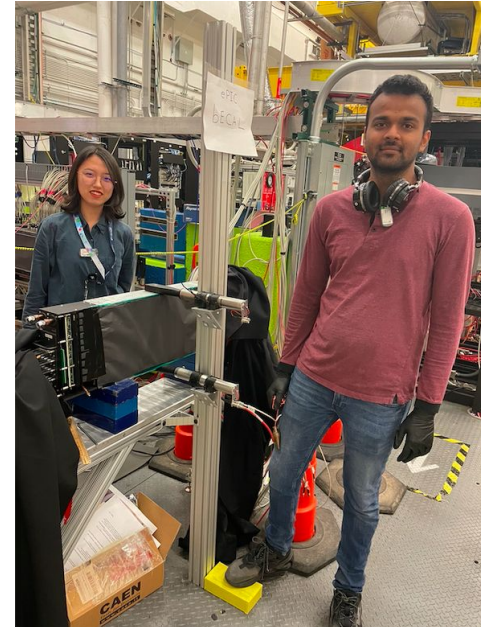- Less consistent at closer distance for both fibers

Reproducibility Tests for NKS-004 and NKD-004 at 10.0 cm

STDEV: 4.413

STDEV: 1.190

current (nA)

measurement #

● NKD-004 (double clad) ● NKS-005 (single clad)

44

Cosmics: Non-MIPs

A few multi-GeV showers as well

Cosmics Setup

Waveforms

```
JANA >>
JANA >> --- Configuration Parameters --
JANA >> OUTPUT_FILENAME = bbcal.root
JANA >> PLUGINS         = glass_prototype
JANA >> THREAD_TIMEOUT  = 30 seconds
JANA >> ---------------------------------
JANA >>Control event: End - Fri Sep  1 16:55:10 2023.0Hz  (avg.: 921.3Hz)
No more events
JANA >>
JANA >>No more event sources
JANA >>Thread 0x7faaaf2d4700 completed gracefully: Mon Sep 18 09:31:35 2023
JANA >>Merging thread 0 (0x7faaaf2d4700) ...

EVIO Processing rate = 562.575 Hz
  NDISPATCHER_STALLED =     176100 (91.6%)
      NPARSER_STALLED =     340679 (88.6%)
   NEVENTBUFF_STALLED =         28 ( 0.0%)

EVIO Statistics for /gluonraid5/data4/rawdata/active/RunPeriod-2023-01/rawdata/Run121303/hd_rawdata_121303_000.evio :
------------------------
    Nblocks: 12
    Nevents: 108208
    Nerrors: 0
Nbad_blocks: 0
Nbad_events: 0

JANA >>Merging event reader thread ...
JANA >> 108208 events processed  (108208 events read) Average rate: 920.9Hz

Closed ROOT file
JANA >>Closing shared object handle 0 ...
HDOPS gluon100:glass_prototype> ▮
```
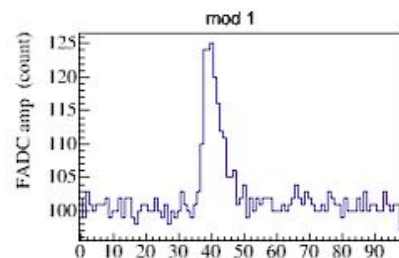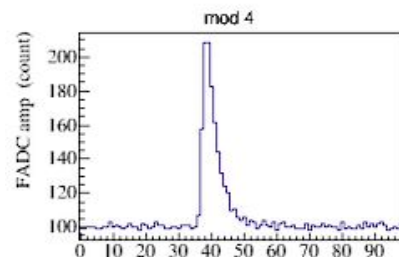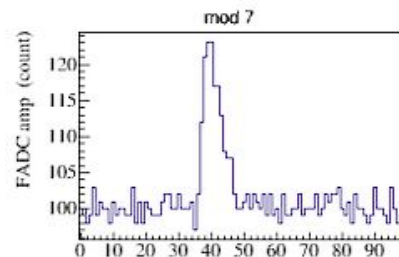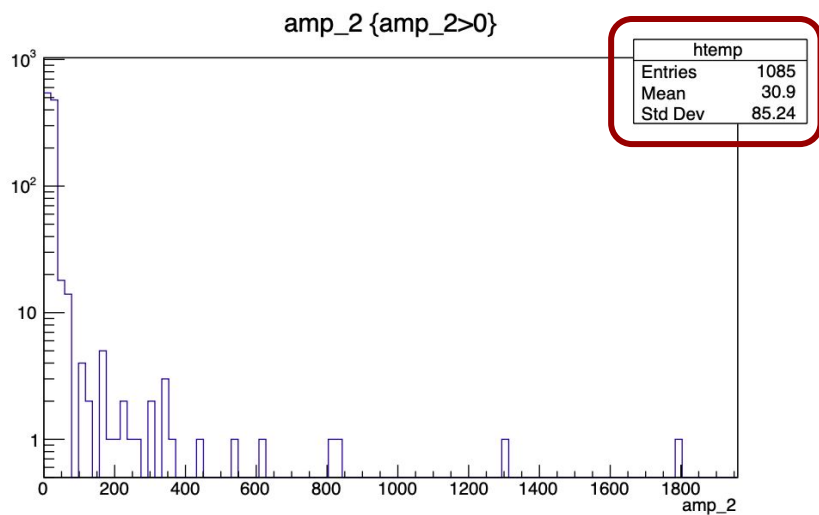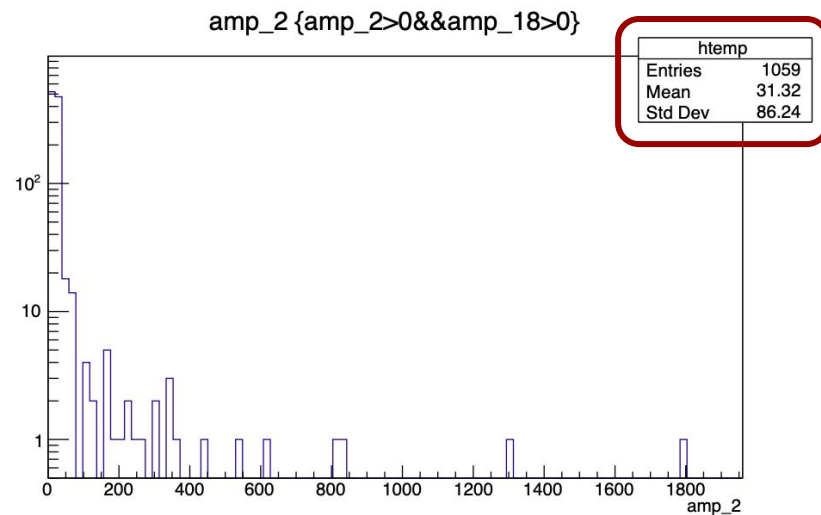

mod 7

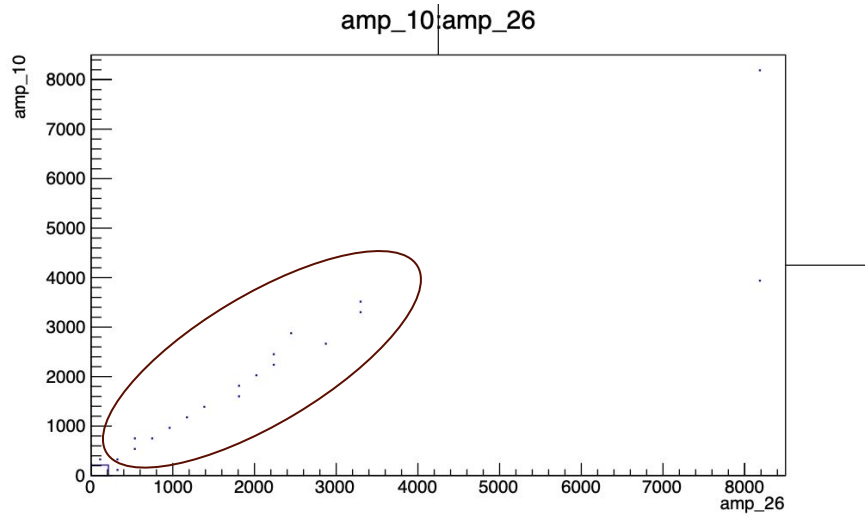mod 4
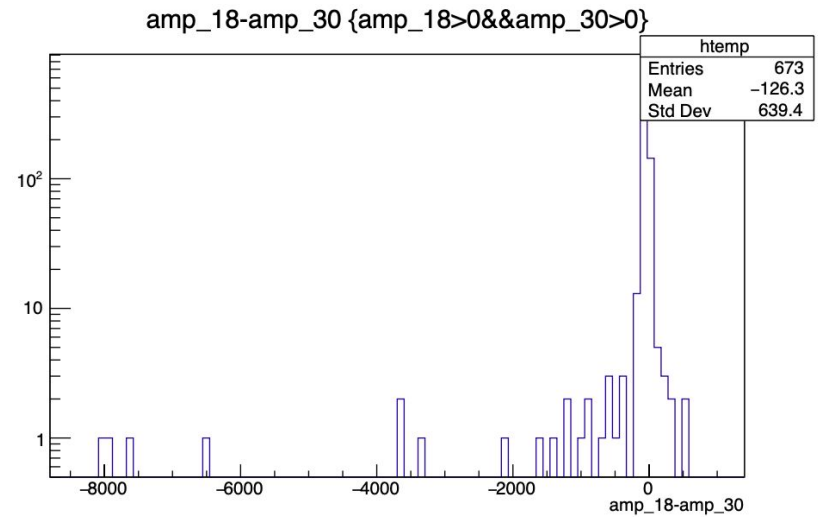

mod 1

47

Amplitudes - Run 121308

Low stats

Progressive cuts

North v South - Run 121308

Gain ratio N-S

n times dE/dx

North v South - dE/dx differences of means

n

N2-N6	**-58**	S2-S6	**-67**	2
N2-N10	**-92**	S2-S10	**-95**	3
N2-N14	**-131**	S2-S14	**-126**	4

GlueX BCAL SiPM
Summing scheme 1:2:3:4

n times dE/dx